



Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at <http://about.jstor.org/participate-jstor/individuals/early-journal-content>.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

concentration. Now this is exactly what we should expect if the surface layer of these solutions consists of a single layer of group molecules of water. Milner shows that the deficiency of salt is 4.1×10^{-11} gram molecules of salt per square centimeter for a normal solution ($c = 0.001$). Hence we may place $q/c = -4.1 \times 10^{-8}$.

This result can be explained if we assume that there is a layer 4.1×10^{-8} cm. thick on the surface which contains no salt. This then should represent the length of the water group molecule. It is interesting to note that practically this same value is obtained with solutions of all the different inorganic salts.

Taking the molecular weight of water in the surface to be 18, we find the cross-section of the water molecule to be 7.3×10^{-16} sq. cm.

It is believed that this method of studying the structure of liquid surfaces will prove to be of very general application. The writer is undertaking experiments to measure the cross-sections of molecules adsorbed on water surfaces from vapors. Thus, benzol vapor greatly lowers the surface tension of water, and in this way some knowledge may be obtained as to the shape of the benzol molecules under different conditions. Of course other liquids than water may also be used.

There is a great deal of available data on surface tension of solutions in the literature which can serve this same purpose. I hope to refer to as many of these cases as possible, in a paper on the constitution of liquids which will soon be submitted for publication in the *Journal of the American Chemical Society*.

¹ Langmuir, I., *J. Amer. Chem. Soc., Easton, Pa.*, **38**, 1916, (2221).

² Pockels, A., *Nature, London*, **43**, 1891, (437-439).

³ Lord Rayleigh, *Phil. Mag., London*, **48**, 1899, (331-337).

⁴ Devaux, H., *Washington, Smithsonian Inst., Ann. Rep.*, 1913, (261-273).

⁵ Marcelin, A., *Paris, Ann. Physique*, **1**, 1914, (19-34).

⁶ Hardy, W. B., *London, Proc. R. Soc., (A)*, **86**, 1912, (610-635).

⁷ Milner, S. R., *Phil. Mag., London*, **13**, 1907, (96-110).

⁸ Szyszkowski, B. v., *Zs. physik. Chem., Leipzig*, **64**, 1908, (385-414).

⁹ Donnon, F. G., and Barker, J. T., *London, Proc. R. Soc., (A)*, **85**, 1911, (557-573).

THE IMPORTANCE OF THE WATER CONTAINED IN THE DEEPER PORTIONS OF THE SUBSOIL

By F. J. Alway and G. R. McDole

MINNESOTA AGRICULTURAL EXPERIMENT STATION

Communicated by R. Pearl, February 10, 1917

The most extreme views are entertained as to the importance of the water contained in the deeper portions of the subsoil—that below the depth penetrated by the roots of crop plants. Thus while McGee¹

considered it to be largely responsible for the crops of extensive areas which would be unproductive if entirely dependent upon the rain and snow which fall upon their surface, and Cameron² sees in it the means of indefinitely maintaining the mineral nutrients of the surface soil, Rotmistrov³ regards it of no importance to those plants whose roots do not reach down to it. Hall⁴ in a recent analysis of the situation has stated: "The evidence on either side is far from being conclusive and more experiments are very desirable."

The present differences in views appears to be due to the failure in laboratory experiments and field studies to take into consideration some physical constant that is directly related to both the lower limit of available moisture and the *water-retaining-capacity* of the soil, if we define the latter as the maximum amount which a soil will carry after it has been saturated and then, protected from both direct evaporation and the indirect effects of this as well as the action of plant roots, allowed to come into approximate moisture equilibrium by the downward movement of the excess of water into the subsoil mass. The lower limit of available moisture as determined by plant-house experiments, in which crop plants were grown in 6-foot cylinders and left unwatered until they matured or died of lack of water, appears to be practically coincident with the hygroscopic coefficient. Up to the present a method of estimating the water retentiveness in the field from one of the physical constants of the soil has not been developed. The laboratory experiments and field studies of the authors make it appear that in the case of soils with hygroscopic coefficients between 14 and 3 this bears a rather simple relation to the hygroscopic coefficient and that in coarser soils, while it bears a much less simple relation, this is still one that may be experimentally determined. As the great majority of the tillable soils of dry-land regions fall within the limits of hygroscopicity mentioned it would appear that through the determination of both the moisture content and the hygroscopic coefficient in the case of samples of the deeper subsoil we could learn both the percentage of the physiologically important water and the departure of this from the maximum which the particular subsoil could retain.

The investigation was carried out in 1912 and 1913, while we were at the Nebraska Agricultural Experiment Station, the field studies being conducted partly in the humid eastern portion of Nebraska and partly in the semi-arid western end of that state.

The soils involved in the experiments included both surface soils and subsoils and ranged in texture from a Dune sand, with a hygroscopic coefficient of 0.6 and a moisture equivalent of 1.5, to a silt loam with

corresponding values of 13.3 and 29.5. In the laboratory experiments we employed cylinders 4 to 6 inches in diameter and of various lengths. These were filled with soils of known hygroscopic coefficients and moisture equivalent, and, except where saturation was desired, we determined the initial moisture content.

Five of the loams, placed in capillary connection with the natural subsoil mass, saturated with water and allowed to stand protected from surface evaporation for several months, lost water until the amount retained bore a close relation to the hygroscopic coefficient, being from 2.1 to 3.1 times this value, according to the particular soil. When a layer of coarse sand or gravel separated the column of loam from the natural subsoil mass or interrupted it the downward movement of the water in the soil above this layer was much delayed. Where the column consisted of successive 2 inch layers of loams differing widely in texture the order of their arrangement exerted no influence upon their final water content.

Soil columns, 30 to 36 inches long, while protected from all loss of moisture at the sides and bottom, were freely exposed to evaporation at the surface for periods varying from a few weeks to half a year. The moisture content, originally uniform and lying between 2 and 3 times the hygroscopic coefficient, fell until it reached, at depths below the first foot, an almost constant minimum with the ratio 1.9 to 2.2.

Employing 2-foot columns of 12 different loams, each with an initial moisture content approximately equal to its hygroscopic coefficient, enough water was added to raise the average moisture content of the column to 1.5 times the hygroscopic coefficient, the water being applied in one experiment to the top and in another to the base of the column. After the cylinders had stood for three or four months, fully protected from evaporation, the distribution of moisture, with regard to the surface to which it had been applied, was found to be the same in both experiments. The maximum distance through which an effect was shown was about 2 feet but in most cases the distance was much less. The maximum final ratio of moisture content to hygroscopic coefficient was found in the section adjacent to the surface of application, where it lay between 1.7 and 2.4. The ratio, while falling within these limits, is not a constant, it not being the same for all the soils that have the same hygroscopic coefficient.

The water-retaining capacity of the loams, as determined by laboratory experiments, was found to bear a somewhat closer relation to the moisture equivalent than to the hygroscopic coefficient, the ratio varying between 0.8 and 1.2.

Coarse sands exhibited a behavior very different from that of the loams. The ratio in the surface 6 inch section, even three months after one inch of water had been applied to the surface, was as high as 6 or 7 while in the second foot it was only 1. The field studies on coarse sands showed as high a final ratio as was observed in the laboratory experiments.

The very limited studies on fine sands indicate that these occupy a position intermediate between the loams and the coarse sands, the ratio of the water-retaining capacity to the hygroscopic coefficient rising as the latter value falls.

Field studies show that when loams, after rains sufficiently heavy to thoroughly moisten them, are protected from losses by evaporation and transpiration, they lose water by downward movement until the ratio of moisture content to hygroscopic coefficient lies between 1.8 and about 2.5, and, accordingly, that on the uplands of dry-land regions this is the ratio to be expected in the deeper subsoil—the portion below the range of plant roots.

A comparatively abrupt transition from the moistened soil to the thoroughly exhausted underlying layers, with ratios of 2 to 2.5 and 1 to 1.1 respectively, is found even several months after liberal rains have fallen, if the subsoil to a considerable depth had previously been exhausted of available water.

The moisture of the deeper subsoil will be able to move upward only so slowly and through such a short distance in a single season that it will be at most of no *practical* benefit to annual crops. To make use of any portion of the precipitation which penetrates beyond the reach of the roots of annual crops it will be necessary to follow such crops at intervals by deep-rooting perennials.

Further experiments of a long-time character are necessary to definitely decide whether the deep subsoil may not in a decade or so contribute sufficient moisture to the subsoil within the reach of the roots of such perennials, 20 to 30 feet, to make such a contribution of some practical importance for such crops.

This is a preliminary extract of a paper transmitted to the *Journal of Agricultural Research*.

¹ McGee, *U. S. Dept. Agric., Bur. Soils, Bull.* 93, 1913, (40).

² Cameron, *The Soil Solution*, 1911, (23).

³ Rotmistrov, *The nature of drouth according to the evidence of the Odessa Experiment Field*. Odessa, 1913.

⁴ *Rept. 84th Meeting Brit. Assoc. Adv. Sci.*, 1914, (641).